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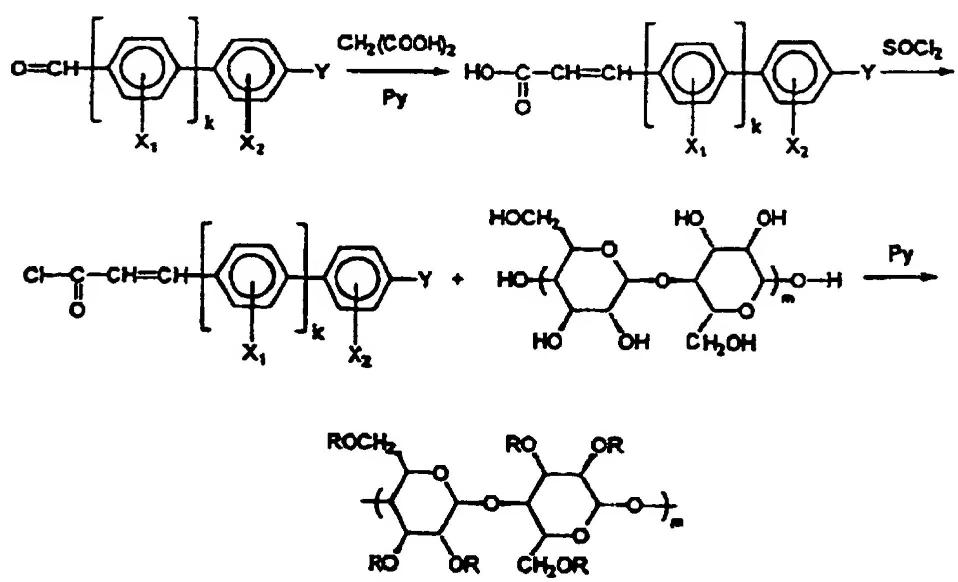
(54) Abstract Title
Alignment layer comprising pyranose or furanose polymer

(57) A liquid crystal display device comprises first and second substances, an alignment layer including a pyranose polymer or a furanose polymer in the form of a cellulose cinnamate on at least one of the first and second substances, and a liquid crystal layer between the first and second substances. The liquid crystal display device is characterized by excellent thermostability, superior anchoring energy and uniform alignment of the liquid crystal achieved in a reduced treatment time without creating any flowing effect in the liquid crystal.

FIG. 1



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A LIQUID CRYSTAL DISPLAY DEVICE

The present invention relates to a liquid crystal display device, and more particularly to a liquid crystal display device having a photo-alignment layer.

It is generally known that a liquid crystal consists of anisotropic molecules. The average direction of the long axes of liquid crystal molecules is called the director of the liquid crystal. The director distribution in a liquid crystal is determined by the anchoring energy on a substrate, and is characterized by a director corresponding to a minimum of the surface energy of the liquid crystal and the anchoring energy. The director is rearranged by an electric field generated during operation of a liquid crystal display device (LCD). An LCD comprises two opposed substrates having liquid crystal therebetween.

In general, to obtain uniform brightness and a high contrast ratio, it is necessary to align the liquid crystal molecules

uniformly in the liquid crystal cell. Several techniques have been proposed using polymers to obtain single or mono-domain homogeneous alignment of liquid crystals. Particularly, it is known that polyimide or polysiloxane-based materials have high quality and good thermostability. The most common technique employed as an alignment method to obtain a mono-domain liquid crystal cell involves forming microgrooves on the surface of the alignment polymer, which provides strong anchoring and stable alignment. In the above-mentioned technique, known as the rubbing method, a substrate coated with an alignment polymer is rubbed with a cloth. The rubbing method is a rapid method which can be applied to large scale LCDs, and thus is widely used in the industry.

The rubbing method, however, has several serious drawbacks. Because the shape of the microgrooves formed on the alignment layer depends on the rubbing cloth and rubbing intensity, the resulting alignment of the liquid crystal is often heterogeneous, causing phase distortion and light scattering. Further, an electrostatic discharge (ESD) generated by rubbing of the polymer surface further generates dust contamination in an active matrix LCD panel, decreasing production yield and damaging the substrate.

In order to solve these problems, a photo-alignment method has been proposed using a polarized ultraviolet light irradiated onto a photosensitive polymer to photo-polymerize the polymer (A. Dyadyusha, V. Kozenkov et al., *Ukr. Fiz. Zhurn.*, 36 (1991) 1059 ; W. M. Gibbons et al., *Nature*, 351 (1991) 49 ; M. Schadt et al., *Jpn. J. Appl. Phys.*, 31 (1992) 2155 ; T. Ya. Marusii & Yu. A. Reznikov, *Mol. Mat.*, 3 (1993) 161 ; EP 0525478 ; and U.S. Patent No. 5,538,823 - a polyvinyl-fluoro cinnamate patent). The alignment capability of the photosensitive polymer is determined by the anisotropy of the photosensitive polymer, which is induced by ultraviolet light irradiation.

In the photo-alignment method, an alignment layer is given an alignment direction by irradiating a substrate coated with a photo-alignment material with a linearly polarized UV light. The photo-alignment layer comprises a polyvinyl cinnamate-based (PVCN) polymer, and as linearly polarized UV light is irradiated, the polymer photo-polymerizes through cross-linking. Cross-linking is generated among the polymers by the UV light energy.

In terms of the direction of the photo-polymers, the alignment direction of the photo-alignment layer has a specific direction in relation to the polymerization direction of the linearly polarized UV light. The alignment direction of the

photo-alignment layer is determined by the direction of the photo-polymers. The pretilt angle of the photo-alignment layer is determined by the incident direction and the irradiating energy of the irradiated UV light. That is to say, the pretilt angle direction and the pretilt angle of the photo-alignment layer are determined by the polarized direction and the irradiating energy of the irradiated UV light.

With regard to photo-alignment, a polarizer is rotated in an arbitrary angle on each domain of the LCD. Then, in response to irradiating UV light, the polarization direction is changed, whereby a multi-domain LCD cell is achieved with multiple domains having different alignment directions in relation to each other.

The photo-alignment method, however, has several drawbacks. For example, it is impossible to apply on a wide scope. Most importantly, low photo-sensitivity of the photo-alignment material results in reduction of anisotropy and thermostability.

UV light irradiation takes a long time using conventional techniques, from approximately 5 to as long as 10 minutes. Low photo-sensitivity and small anisotropy make the anchoring energy of the final photo-alignment layer weak. Moreover, when the liquid crystal is injected into the LCD, it is required that the injection be made at a high temperature. Low thermostability

induces a flowing effect on the substrates, which can be observed as a ripple pattern in the liquid crystal upon injection between the substrates. Finally, disclination owing to the uniform alignment of liquid crystals remains as a problem to be solved.

Accordingly, the present invention is directed to a LCD that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide an LCD having good thermostability and photo-sensitivity.

Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described herein, the liquid crystal display device of the present invention comprises first and second substrates, an alignment layer including a pyranose or a furanose polymer on at

least the first substrate, and a liquid crystal layer between the first and second substrates.

The liquid crystal display device of the present invention preferably comprises a second alignment layer on the second substrate. The second alignment layer includes a material selected from the group consisting of a pyranose polymer, a furanose polymer, polyvinyl cinnamate, polysiloxane cinnamate, polyvinyl alcohol, polyamide, polyimide, polyamic acid and silicone dioxide.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

For a better understanding of the present invention, embodiments will now be described by way of example, with reference to the accompanying drawings, in which:

Fig. 1 illustrates the synthesis of a cellulose cinnamate according to an embodiment of the present invention;

Fig. 2 schematically illustrates an embodiment of a system of light irradiation of a photo-alignment layer in accordance with the present invention; and

Fig. 3 is a sectional view of an embodiment of a liquid crystal display device according to the present invention.

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

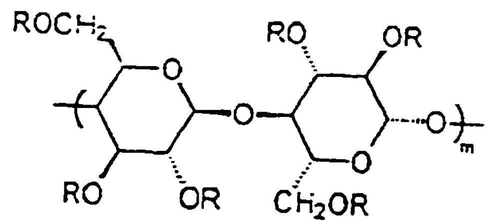
A liquid crystal display device of the present invention will now be explained in detail in conjunction with the accompanying drawings.

According to an embodiment of the present invention, in order to enhance the sensitivity of a photo-alignment layer for a liquid crystal device and obtain thermostable anchoring of the liquid crystal, a cellulose cinnamate (CelCN) is used as the photo-alignment material. Several different forms of CelCN suitable for use in the present invention are obtained as derivatives of cellulose or cellulose acetate and cinnamoyl chloride having various substitution ratios.

Pyranose polymers and furanose polymers are particularly preferred for use as the cellulose cinnamates of the present

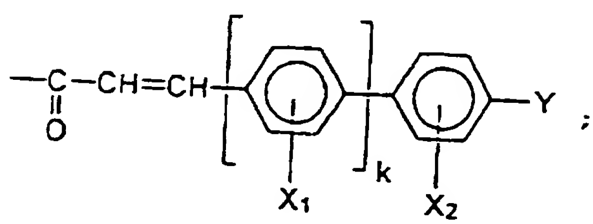
invention.

Pyranose polymers suitable for use in the present invention are characterized by the following chemical formula:



wherein m is 10 to 10,000;

R is at least one member selected from the group consisting of $-\underset{\underset{O}{\|}}{C}-C_nH_{2n+1}$ and



n is 1 to 10;

X_1 and X_2 are each selected from the group consisting of hydrogen, fluorine, chlorine, methyl and methoxy;

k is 0 to 1; and

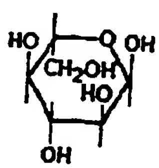
Y is selected from the group consisting of hydrogen, fluorine, chlorine, cyano, trifluoromethyl, trifluoromethoxy, $C_{n'}H_{2n'+1}$ and $OC_{n'}H_{2n'+1}$, wherein n' is 1 to 10.

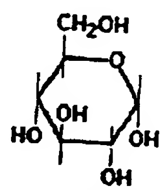
In a particularly preferred form of the invention, the

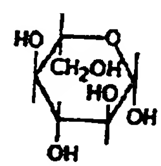
alignment layer is characterized by 0 to 2 $-\underset{\underset{O}{\|}}{C}-C_nH_{2n+1}$

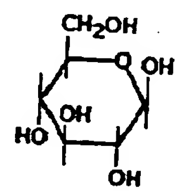
constituents per glucopyranose ring, wherein n is 1 to 10.

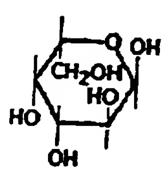
As is well-known in the art, the four possible glucopyranose conformations and the four possible galactopyranose conformations, each of which conformations is within the scope of the terms cellulose and cellulose acetate as used in the present invention, are illustrated by the following formulas:

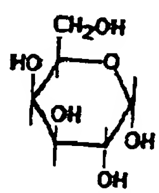

α-L-Glucopyranose

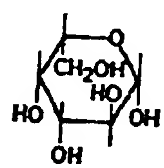

α-D-Glucopyranose


β-L-Glucopyranose


β-D-Glucopyranose


α-L-Galactopyranose


α-D-Galactopyranose


β-L-Galactopyranose

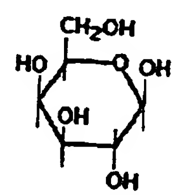

β-D-Galactopyranose

Fig. 1 shows the synthesis of a cellulose cinnamate according to an embodiment of the present invention. A cinnamic

acid is first prepared by reacting a benzaldehyde with malonic acid in pyridine and piperidine. The cinnamic acid is then reacted with thionyl chloride to produce a cinnamoyl chloride derivative. The CelCN is finally synthesized by reacting cellulose, or cellulose acetate, with the cinnamoyl chloride derivative in an inert solvent (such as chloroform, nitrobenzene, chlorobenzene, or the like). The reaction mixture is diluted with methanol, filtered, dried in a vacuum, and milled by a vibrating mill, whereupon the CelCN is obtained.

A process of forming an alignment layer according to an embodiment of the present invention comprises the following three steps.

First, a polymer solution is prepared using chloroform ($CHCl_3$)as a solvent. The concentration of the polymer determines the ultimate thickness of the alignment layer on the LCD substrates. To form a film having a thickness of approximately 1 μm, a CelCN solution of 10 g/l is selected for coating the substrate.

Second, a drop of the CelCN solution is placed in the center of the substrate using a measuring pipette, followed by spin-coating while centrifuging at a rotation speed of 3000 rpm for 30 seconds. The produced film is immediately prebaked at 180 °C for

1 hour.

Third, the initially isotropic polymer film is irradiated with polarized UV light having a wavelength λ below 365 nm to render it anisotropic, with either a positive or a negative dielectric. The irradiation time is more than 5 seconds, and the intensity of UV light is about 5 mW/cm².

Fig. 2 illustrates a scheme of light irradiation of a photo-alignment layer of the present invention.

As shown in Fig. 2, an embodiment of the light irradiating procedure utilizes a substrate 100, a photo-alignment layer 50 including a CelCN on substrate 100, a lamp 10 for irradiating UV light over photo-alignment layer 50, and a polarizer 30 for polarizing the light irradiated from lamp 10.

Lamp 10 is a Halogen (Hg) lamp. Light having an average power of 500 W is transmitted from a lens of the halogen lamp, polarized by polarizer 30, and irradiated onto photo-alignment layer 50 at a power of 5 mW/cm² for about 0.5 to about 180 seconds, more preferably about 0.5 to about 60 seconds, and most preferably about 3 to about 60 seconds.

The alignment obtained from the CelCN polymers of the present invention has a stronger anchoring energy compared with the alignment obtained from conventional photo-alignment

materials. The values of the anchoring energy of CelCN versus typical prior art photo-alignment materials, including polyvinyl fluorocinnamate (PVCN-F) and polysiloxane cinnamate (PSCN), have been measured. The results are shown in the following TABLE 1:

TABLE 1

Material	**Irradiation Time (seconds)**	**Anchoring Energy (erg/cm^2)**
cellulose 4-fluorocinnamate	5	greater than 10^{-2}
cellulose 4-fluorocinnamate	300	greater than 10^{-2}
polyvinyl-fluorocinnamate	5	3×10^{-4}
polyvinyl-fluorocinnamate	300	10^{-2}
polysiloxane-cinnamate	5	bad alignment; measuring failure
polysiloxane-cinnamate	300	5×10^{-3}

To estimate the thermostability of the CelCN, the quality of the alignment layer was checked using an electro-optical technique. Electro-optical response, in terms of cell

transparency ratio between crossed and parallel polarizers, anchoring energy and surface density of the alignment layer were each measured in a twisted nematic (TN) cell containing samples of the CelCN layers. The cell was heated to about 120 °C and kept at this temperature for 4 hours. After cooling the samples to room temperature, it was revealed that the performance characteristics were maintained unchangeably.

Among its other advantages, the present invention thus significantly reduces UV irradiation time. Whereas prior art photo-alignment techniques involved UV irradiation for anywhere from 5 to 10 minutes, the present invention provides a method which successfully achieves photo-alignment using UV irradiation in anywhere from about 0.5 seconds to one minute.

Preferred embodiments of the present invention will now be described in further detail. It should be understood that these examples are intended to be illustrative only and that the present invention is not limited to the conditions, materials or devices recited therein.

EXAMPLE 1

- Synthesis of 4-fluorocinnamic acid -

A mixture of 0.1 mol 4-fluorobenzaldehyde, 0.15 mol malonic acid, and 0.1 ml piperidine in 30 ml pyridine is boiled for 10 hours, cooled, and treated with 150 ml HCl having a 10 % concentration. The precipitate is filtered and crystallized with ethanol. The yield of 4-fluorocinnamic acid is 68 % and the melting point is 211 °C.

The following compounds are synthesized in a similar manner:

2-fluoro cinnamic acid;

3-fluoro cinnamic acid;

3-chloro cinnamic acid;

4-chloro cinnamic acid;

2-methyl cinnamic acid;

4-phenyl cinnamic acid;

4-methoxy cinnamic acid;

4-pentoxy cinnamic acid;

4-heptyloxy cinnamic acid;

4-nonyloxy cinnamic acid;

4-(4-pentoxyphenyl)cinnamic acid;

4-trifluoromethoxy cinnamic acid;

4-trifluoromethyl cinnamic acid;

4-pentyl cinnamic acid; and

4-methoxy-3-fluorocinnamic acid.

EXAMPLE 2

- Synthesis of cellulose cinnamate -

A mixture of 0.05 mol cinnamoyl chloride (prepared from a cinnamic acid produced in Example 1, an excess of thionyl chloride, and catalytic quantities of dimethyl formamide), 0.01 mol cellulose, and 0.04 mol pyridine in 20 ml nitrobenzene is heated for 24 hours at 120 °C, cooled, and diluted with methanol. The reaction product is filtered, washed with methanol and water, dried in a vacuum, and subsequently milled by a vibrating mill.

Pyranose polymers are produced in the above manner using each of the cinnamic acids produced in Example 1. The yield of cellulose cinnamate is approximately 65% to 92%. Thin layer chromatography (TLC) reveals there is no cinnamic acid in the reaction products.

EXAMPLE 3

- Synthesis of cellulose acetate cinnamate -

A mixture of 0.03 mol cinnamoyl chloride (prepared from a

cinnamic acid produced in Example 1, an excess of thionyl chloride, and catalytic quantities of dimethyl formamide), 0.01 mol cellulose acetate, and 0.03 mol pyridine in 20 ml chloroform is boiled for 24 hours, cooled, and diluted with methanol. The reaction product is filtered, washed with methanol and water, dried in a vacuum, and subsequently milled by a vibrating mill.

Pyranose acetate polymers are produced in the above manner using each of the cinnamic acids produced in Example 1. The yield of cellulose acetate cinnamate is approximately 65% to 92%. Thin layer chromatography (TLC) confirms there is no cinnamic acid in the reaction products.

Fig. 3 is a sectional view of an embodiment of a liquid crystal display device of the present invention.

As shown in Fig. 3, the LCD comprises first and second substrates 100 and 101, respectively, a thin film transistor (TFT) 70 on first substrate 100, a first alignment layer 50 formed entirely over TFT 70 and first substrate 100, a second alignment layer 51 formed on second substrate 101, and a liquid crystal layer 90 injected between first and second substrates 100 and 101.

First and/or second alignment layers 50, 51 include a pyranose or furanose polymer, for example the CelCN shown in Fig.

1. The CelCN provides good uniform alignment in a short irradiation time. For example, irradiation for as little as 0.5 seconds gives a stable alignment.

The pyranose and furanose polymers preferably comprise both photo-sensitive constituents and non-photo-sensitive constituents which are composited in a specific ratio. The pyranose and furanose polymers can be composited with only one constituent from each of photo-sensitive and non-photo-sensitive constituents, or one or more different photo-sensitive and/or non-photo-sensitive constituents.

Suitable photo-sensitive constituents for use in the pyranose and furanose polymers of the present invention include an array of cinnamoyl derivatives, which can include substituents such as hydrogen, fluorine, chlorine, cyano, trifluoromethyl, trifluoromethoxy, $C_{n'}H_{2n'+1}$, $OC_{n'}H_{2n'+1}$, phenyl and $C_6H_4OC_{n'}H_{2n'+1}$, wherein n' is 1 to 10.

Suitable non-photo-sensitive constituents for use in the pyranose and furanose polymers of the present invention include various ester derivatives, such as $-\underset{\underset{O}{\|}}{C}-C_nH_{2n+1}$, wherein n is 1 to 10.

When UV light is irradiated onto the first and/or second

alignment layers at least once, the alignment angle, the alignment direction thereof, the pretilt angle and the pretilt angle direction thereof are determined and alignment stability of the liquid crystal is achieved.

As the light used in the photo-alignment method, light in the UV range is preferable. It is not advantageous to use unpolarized light, linearly polarized light, or partially polarized light.

Moreover, it is contemplated as within the scope of the present invention that only one substrate of the first and second substrates be photo-aligned using the above-described method while the other substrate is not so treated. If both substrates are photo-aligned, it is within the scope of the invention that the other substrate be treated with polyamide or polyimide as the alignment material and that the alignment be accomplished by prior art rubbing methods. It is also possible to use a photo-sensitive material such as polyvinyl cinnamate (PVCN) or polysiloxane cinnamate (PSCN) as the alignment material for the other substrate and accomplish the alignment using photo-alignment methods.

As to the nature of liquid crystal layer 90, it is possible to align the long axes of the liquid crystal molecules parallel

with the first and second substrates to produce a homogeneous alignment. It is also possible to align the long axes of the liquid crystal molecules perpendicular to the first and second substrates to achieve a homeotropic alignment. Moreover, it is possible to align the long axes of the liquid crystal molecules with a specific predetermined angle in relation to the substrates, with a tilted alignment in relation to the substrates, with a twisted alignment in relation to the substrates, or in an alignment parallel to one substrate and perpendicular to the other substrate to provide a hybrid homogeneous-homeotropic alignment. It is thus essentially within the scope of the present invention to apply any mode of alignment of the liquid crystal molecules in relation to the substrates as may be desired, such choices being apparent to one of ordinary skill in the art.

The first and/or second alignment layers can be divided into two or more domains by creating different directional alignments of the liquid crystal molecules on each domain in relation to the direction of the substrates. Accordingly, a multi-domain LCD such as a 2-domain LCD, a 4-domain LCD, and so on can be obtained, wherein the liquid crystal molecules in each domain are driven differently.

An LCD made in accordance with the embodiments is characterized by excellent thermostability. It is thus possible to inject the liquid crystal into the liquid crystal device at room temperature while preventing and avoiding any flowing effect from generating, as occurs in conventional techniques. Furthermore, the photo-alignment layer of the embodiments possess excellent photosensitivity, adhesion, and strong anchoring energy. As a result, it is possible to align the liquid crystal effectively and increase alignment stability of the liquid crystal.

It will be apparent to those skilled in the art that various modifications and variations can be made in the liquid crystal display device of the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

Claims:

1. A liquid crystal display device, comprising:

first and second substrates;

a first alignment layer including a pyranose polymer on said first substrate; and

a liquid crystal layer between said first and second substrates.

2. The liquid crystal display device according to claim 1,

further comprising a second alignment layer on said second substrate.

3. The liquid crystal display device according to claim 2,

wherein said second alignment layer includes a material selected from the group consisting of a pyranose polymer, a furanose polymer, polyvinyl cinnamate, polysiloxane cinnamate, polyvinyl alcohol, polyamide, polyimide, polyamic acid and silicone dioxide.

4. The liquid crystal display device according to claim 1, 2 or 3, wherein liquid crystal in said liquid crystal layer has

a positive dielectric anisotropy.

5. The liquid crystal display device according to claim 1, 2 or 3, wherein liquid crystal in said liquid crystal layer has a negative dielectric anisotropy.

6. The liquid crystal display device according to any one of the preceding claims, wherein at least one of said first and second alignment layers is divided into at least two domains, for driving liquid crystal molecules in said liquid crystal layer differently on each domain.

7. The liquid crystal display device according to any one of the preceding claims, wherein liquid crystal molecules in said liquid crystal layer align homogeneously in relation to at least one of said first and second substrates.

8. The liquid crystal display device according to any one of claims 1 to 6, wherein liquid crystal molecules in said liquid crystal layer align homeotropically in relation to at least one of said first and second substrates.

9. The liquid crystal display device according to any one of the preceding claims, wherein liquid crystal molecules in said liquid crystal layer are arranged in tilted alignment in relation to at least one of said first and second substrates.

10. The liquid crystal display device according to any one of claims 1 to 8, wherein liquid crystal molecules in said liquid crystal layer are arranged in twisted alignment in relation to at least one of said first and second substrates.

11. The liquid crystal display device according to any one of claims 1 to 6 or 9 to 10, wherein liquid crystal molecules in said liquid crystal layer align homogeneously in relation to one substrate of said first and second substrates and align homeotropically in relation to another substrate of said first and second substrates.

12. The liquid crystal display device according to any one of the preceding claims, wherein said pyranose polymer

includes at least one constituent selected from the group consisting of photo-sensitive constituents and non-photo-sensitive constituents.

13. The liquid crystal display device according to claim 12, wherein said photo-sensitive constituent is a cinnamoyl derivative.

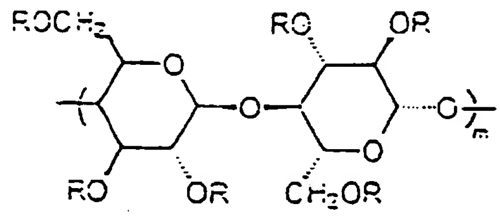
14. The liquid crystal display device according to claim 13, wherein said cinnamoyl derivative includes at least one member selected from the group consisting of hydrogen, fluorine, chlorine, cyano, trifluoromethyl, trifluoromethoxy, C_nH_{2n+1}, OC_nH_{2n+1}, phenyl and $C_6H_4OC_nH_{2n+1}$, wherein n is 1 to 10.

15. The liquid crystal display device according to claim 12, 13 or 14, wherein said non-photo-sensitive constituent is an ester derivative.

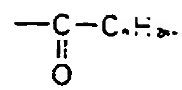
16. The liquid crystal display device according to claim 15, wherein said ester derivative is $-\underset{\underset{O}{\|}}{C}-C_nH_{2n+1}$

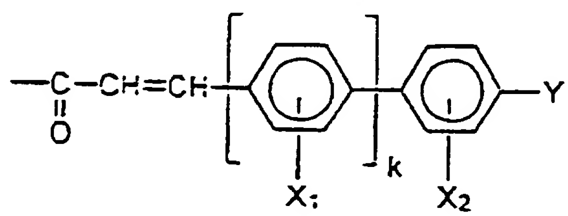
and n is 1 to 10.

17. The liquid crystal display device according to claim 1, wherein said pyranose polymer is



wherein m is 10 to 10,000;

R is selected from the group consisting of 

and 

n is 1 to 10;

X_1 and X_2 are each selected from the group consisting of hydrogen, fluorine, chlorine, methyl and methoxy;

k is 0 to 1; and

Y is selected from the group consisting of hydrogen, fluorine, chlorine, cyano, trifluoromethyl, trifluoromethoxy, $C_{n'}H_{2n'+1}$ and $OC_{n'}H_{2n'+1}$, wherein n' is 1 to 10.

18. The liquid crystal display device according to claim 17, wherein said pyranose polymer has 0 to 2

$-\underset{\underset{O}{\|}}{C}-C_nH_{2n+1}$ constituents per one glucopyranose ring, and n is 1 to 10.

19. The liquid crystal display device according to any one of the preceding claims, wherein said pyranose polymer is cellulose 4-fluorocinnamate.

20. A liquid crystal display device, comprising :

first and second substrates ;

a first alignment layer including furanose polymer on said first substrate ; and

a liquid crystal layer between said first and second substrates.

21. The liquid crystal display device according to claim 20, further comprising a second alignment layer on said second substrate.

22. The liquid crystal display device according to claim 21, wherein said second alignment layer includes a material selected from the group consisting of pyranose polymer, furanose polymer, polyvinylcinnamate, polysiloxanecinnamate,

polyvinylalcohol, polyamide, polyimide, polyamic acid, and silicondioxide.

23. The liquid crystal display device according to claim 20, 21 or 22, wherein liquid crystal in said liquid crystal layer has a positive dielectric anisotropy.

24. The liquid crystal display device according to claim 20, 21 or 22, wherein liquid crystal in said liquid crystal layer has a negative dielectric anisotropy.

25. The liquid crystal display device according to any one of claims 20 to 24, wherein said first or second alignment layer is divided into at least two domains, to drive differently liquid crystal molecules in said liquid crystal layer on each domain.

26. The liquid crystal display device according to any one of claims 20 to 25, wherein liquid crystal molecules in said liquid crystal layer align homogeneous against said first or second substrate.

27. The liquid crystal display device according to any one of claims 20 to 25, wherein liquid crystal molecules in said liquid crystal layer align homeotropic against said first or second substrate.

28. The liquid crystal display device according to any one of claims 20 to 27, wherein liquid crystal molecules in said liquid crystal layer align tilted against said first or second substrate.

29. The liquid crystal display device according to any one of claims 20 to 27, wherein liquid crystal molecules in said liquid crystal layer align twisted against said first or second substrate.

30. The liquid crystal display device according to any one of claims 20 to 25 or 28 to 29, wherein liquid crystal molecules in said liquid crystal layer align homogeneous against one substrate of said first and second substrates and align homeotropic against the other substrate.

31. The liquid crystal display device according to any one of claims 20 to 30, wherein said furanose polymer comprises photo-sensitive part or non-photo-sensitive part.

32. The liquid crystal display device according to claim 31, wherein said photo-sensitive part is selected from the group consisting of cinnamoyl derivatives.

33. The liquid crystal display device according to claim 32, wherein said cinnamoyl derivative includes hydrogen, fluorine, chlorine, cyano, trifluoromethyl, trifluoromethoxy, C_nH_{2n+1}, OC_nH_{2n+1}, phenyl, or $C_6H_4OC_nH_{2n+1}$ (n is 1 to 10).

34. The liquid crystal display device according to claim 31, 32 or 33, wherein said non-photo-sensitive part is selected from the group consisting of ester derivatives.

35. The liquid crystal display device according to claim 34, wherein said ester derivatives is $-\underset{\underset{O}{\|}}{C}-C_nH_{2n+1}$

(n is 1 to 10).

36. An alignment layer for a liquid crystal display device, wherein the alignment layer includes a pyranose polymer and/or a furanose polymer.

37. A liquid crystal display device substantially as hereinbefore described with reference to and/or substantially as illustrated in any one of or in any combination of the accompanying drawings.

38. An alignment layer for a liquid crystal display device, substantially as hereinbefore described with reference to and/or substantially as illustrated in any one of or in any combination of the accompanying drawings.

The Patent Office

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INVESTOR IN PEOPLE

Application No: GB 9825387.5
Claims searched: 1 to 38

Examiner: Julyan Elbro
Date of search: 8 February 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G2F (FCT)

Int Cl (Ed.6): G02F 1/1337

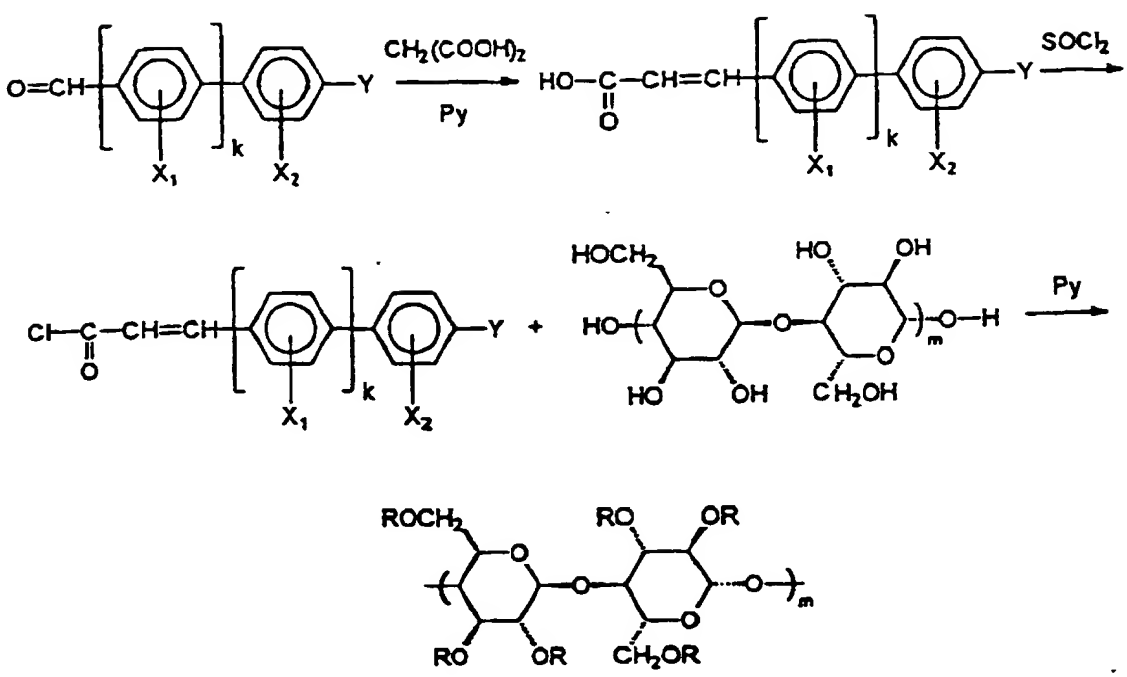
Other: ONLINE: WPI JAPIO INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0261712 A1 PHILIPS see page 13 paragraph 3.	
A	WO 94/28458 A1 HOECHST	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

FIG. 1



O=CH
Y
X1
k
X2
CH2(COOH)2
Py
HO—C—CH=CH
O
SOCl2
Cl—C—CH=CH
HOCH2
HO
OH
CH2OH
m
O—H
ROCH2
RO
OR
CH2OR

FIG. 2

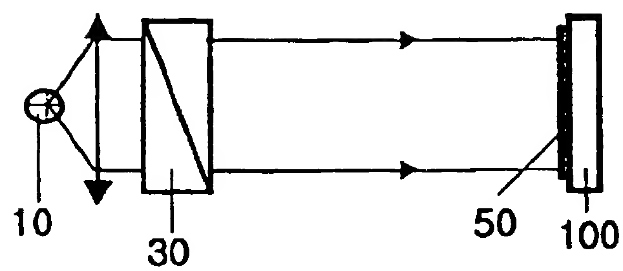
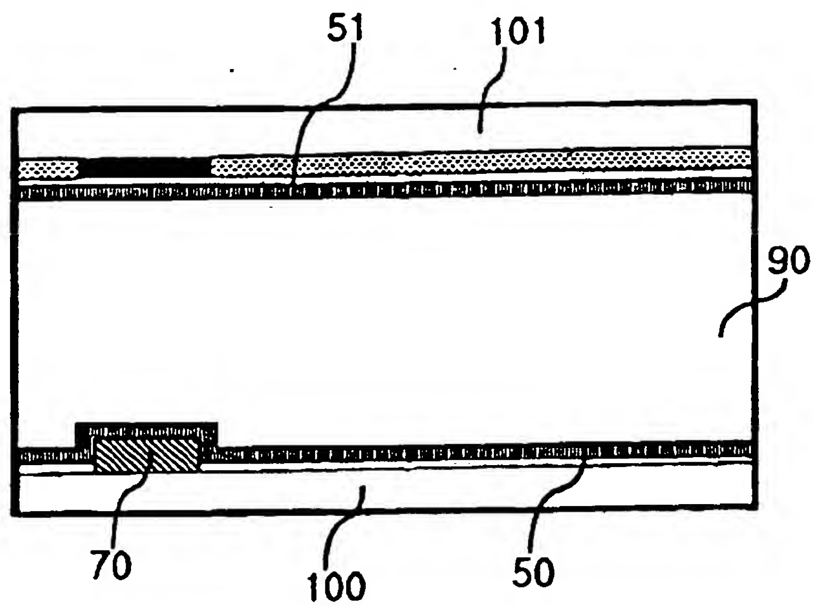


FIG. 3



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A liquid crystal display device

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FIG. 1

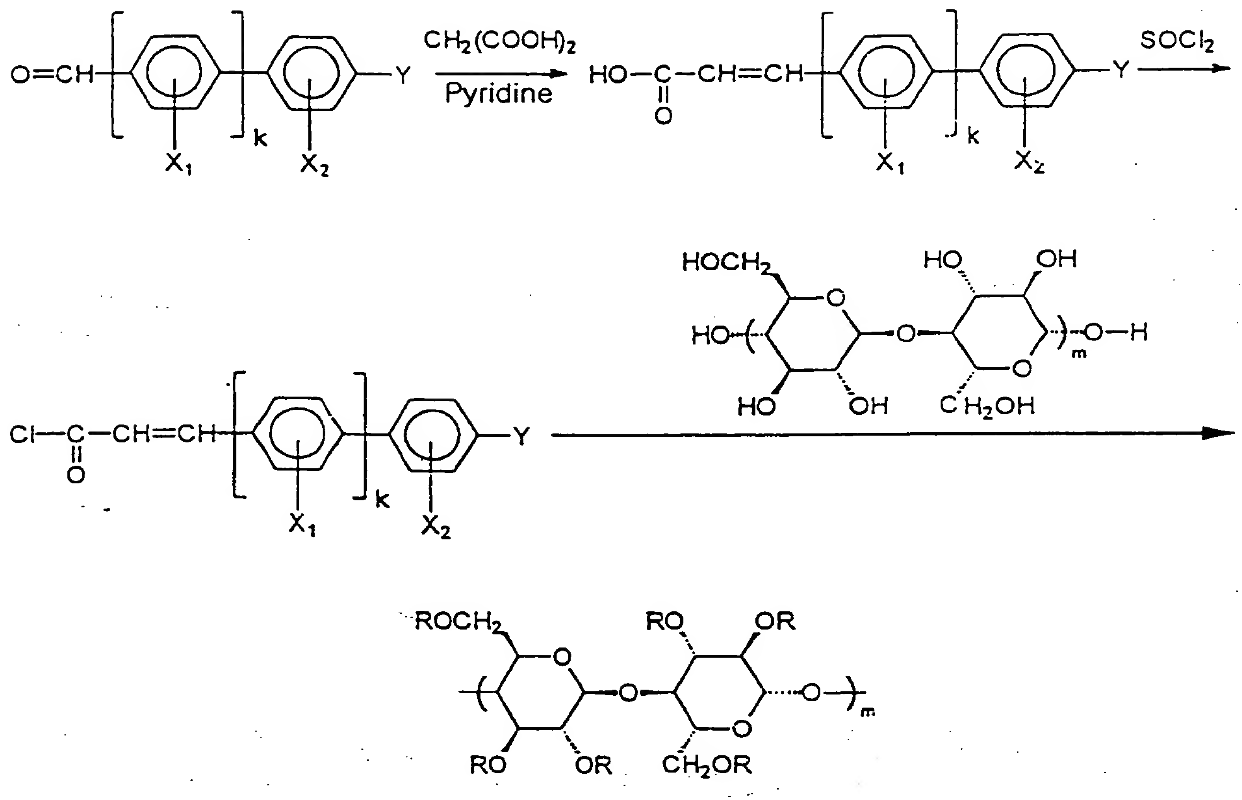


FIG. 2

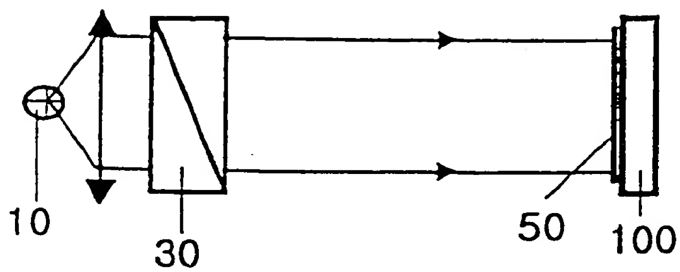
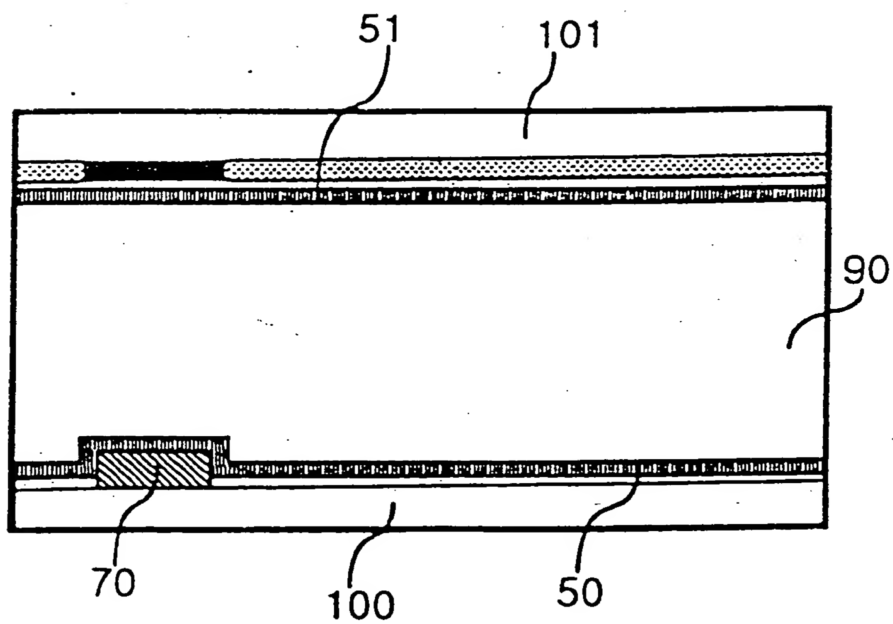


FIG. 3



2331591

A LIQUID CRYSTAL DISPLAY DEVICE

The present invention relates to a liquid crystal display device, and more particularly to a liquid crystal display device having a photo-alignment layer.

It is generally known that a liquid crystal consists of anisotropic molecules. The average direction of the long axes of liquid crystal molecules is called the director of the liquid crystal. The director distribution in a liquid crystal is determined by the anchoring energy on a substrate, and is characterized by a director corresponding to a minimum of the surface energy of the liquid crystal and the anchoring energy. The director is rearranged by an electric field generated during operation of a liquid crystal display device (LCD). An LCD comprises two opposed substrates having liquid crystal therebetween.

In general, to obtain uniform brightness and a high contrast ratio, it is necessary to align the liquid crystal molecules

uniformly in the liquid crystal cell. Several techniques have been proposed using polymers to obtain single or mono-domain homogeneous alignment of liquid crystals. Particularly, it is known that polyimide or polysiloxane-based materials have high quality and good thermostability. The most common technique employed as an alignment method to obtain a mono-domain liquid crystal cell involves forming microgrooves on the surface of the alignment polymer, which provides strong anchoring and stable alignment. In the above-mentioned technique, known as the rubbing method, a substrate coated with an alignment polymer is rubbed with a cloth. The rubbing method is a rapid method which can be applied to large scale LCDs, and thus is widely used in the industry.

The rubbing method, however, has several serious drawbacks. Because the shape of the microgrooves formed on the alignment layer depends on the rubbing cloth and rubbing intensity, the resulting alignment of the liquid crystal is often heterogeneous, causing phase distortion and light scattering. Further, an electrostatic discharge (ESD) generated by rubbing of the polymer surface further generates dust contamination in an active matrix LCD panel, decreasing production yield and damaging the substrate.

In order to solve these problems, a photo-alignment method has been proposed using a polarized ultraviolet light irradiated onto a photosensitive polymer to photo-polymerize the polymer (A. Dyadyusha, V. Kozenkov et al., *Ukr. Fiz. Zhurn.*, 36 (1991) 1059 ; W. M. Gibbons et al., *Nature*, 351 (1991) 49 ; M. Schadt et al., *Jpn. J. Appl. Phys.*, 31 (1992) 2155 ; T. Ya. Marusii & Yu. A. Reznikov, *Mol. Mat.*, 3 (1993) 161 ; EP 0525478 ; and U.S. Patent No. 5,538,823 - a polyvinyl-fluoro cinnamate patent). The alignment capability of the photosensitive polymer is determined by the anisotropy of the photosensitive polymer, which is induced by ultraviolet light irradiation.

In the photo-alignment method, an alignment layer is given an alignment direction by irradiating a substrate coated with a photo-alignment material with a linearly polarized UV light. The photo-alignment layer comprises a polyvinyl cinnamate-based (PVCN) polymer, and as linearly polarized UV light is irradiated, the polymer photo-polymerizes through cross-linking. Cross-linking is generated among the polymers by the UV light energy.

In terms of the direction of the photo-polymers, the alignment direction of the photo-alignment layer has a specific direction in relation to the polymerization direction of the linearly polarized UV light. The alignment direction of the

photo-alignment layer is determined by the direction of the photo-polymers. The pretilt angle of the photo-alignment layer is determined by the incident direction and the irradiating energy of the irradiated UV light. That is to say, the pretilt angle direction and the pretilt angle of the photo-alignment layer are determined by the polarized direction and the irradiating energy of the irradiated UV light.

With regard to photo-alignment, a polarizer is rotated in an arbitrary angle on each domain of the LCD. Then, in response to irradiating UV light, the polarization direction is changed, whereby a multi-domain LCD cell is achieved with multiple domains having different alignment directions in relation to each other.

The photo-alignment method, however, has several drawbacks. For example, it is impossible to apply on a wide scope. Most importantly, low photo-sensitivity of the photo-alignment material results in reduction of anisotropy and thermostability.

UV light irradiation takes a long time using conventional techniques, from approximately 5 to as long as 10 minutes. Low photo-sensitivity and small anisotropy make the anchoring energy of the final photo-alignment layer weak. Moreover, when the liquid crystal is injected into the LCD, it is required that the injection be made at a high temperature. Low thermostability

induces a flowing effect on the substrates, which can be observed as a ripple pattern in the liquid crystal upon injection between the substrates. Finally, disclination owing to the uniform alignment of liquid crystals remains as a problem to be solved.

Accordingly, the present invention is directed to a LCD that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide an LCD having good thermostability and photo-sensitivity.

The liquid crystal display device of the present invention comprises first and second substrates, an alignment layer including a pyranose or a furanose polymer on at least the first substrate, and a liquid crystal layer between the first and second substrates.

The liquid crystal display device of the present invention preferably comprises a second alignment layer on the second substrate. The second alignment layer includes a material selected from pyranose polymers, furanose polymers, polyvinyl cinnamate, polysiloxane cinnamate, polyvinyl alcohol, polyamides, polyimides, polyamic acid and silicone dioxide.

In one aspect the present invention provides an alignment layer for a liquid crystal display device, wherein the alignment layer includes a pyranose polymer and/or a furanose polymer.

For a better understanding of the present invention, embodiments will now be described by way of example, with reference to the accompanying drawings, in which:

Fig. 1 illustrates the synthesis of a cellulose cinnamate according to an embodiment of the present invention;

Fig. 2 schematically illustrates an embodiment of a system of light irradiation of a photo-alignment layer in accordance with the present invention; and

Fig. 3 is a sectional view of an embodiment of a liquid crystal display device according to the present invention.

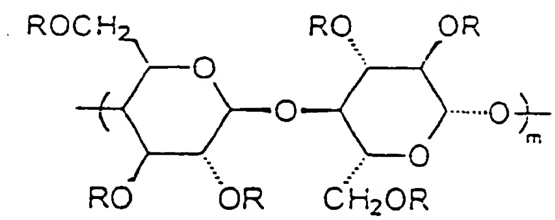
Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

A liquid crystal display device of the present invention will now be explained in detail in conjunction with the accompanying drawings.

The pyranose or furanose polymer included in the first alignment layer serves as a photo-alignment material.

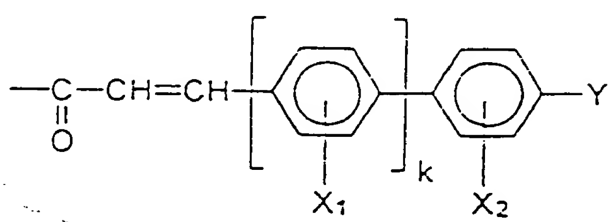
According to an embodiment of the present invention, in order to enhance the sensitivity of a photo-alignment layer for a liquid crystal device and obtain thermostable anchoring of the liquid crystal, a cellulose cinnamate (CelCN) is used as the photo-alignment material. Several different forms of CelCN suitable for use in the present invention are obtained as derivatives of cellulose or cellulose acetate and cinnamoyl chloride having various substitution ratios.

Pyranose polymers suitable for use in the present invention are characterized by the following chemical formula:



wherein m is 10 to 10,000;

R is at least one member selected from the group consisting of $-\mathrm{C}(=\mathrm{O})-C_nH_{2n+1}$ and



;

n is 1 to 10;

X_1 and X_2 are each selected from the group consisting of hydrogen, fluorine, chlorine, methyl and methoxy;

k is 0 to 1; and

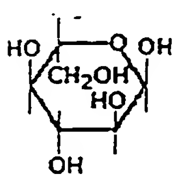
Y is selected from the group consisting of hydrogen, fluorine, chlorine, cyano, trifluoromethyl, trifluoromethoxy, $C_{n'}H_{2n'+1}$ and $OC_{n'}H_{2n'+1}$, wherein n' is 1 to 10.

In a particularly preferred form of the invention, the

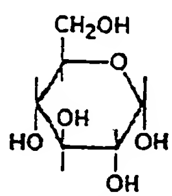
alignment layer is characterized by 0 to 2 $-\underset{\substack{\| \\ O}}{C}-C_nH_{2n+1}$

constituents per glucopyranose ring, wherein n is 1 to 10.

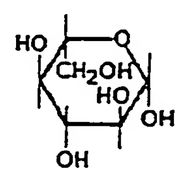
As is well-known in the art, the four possible glucopyranose conformations and the four possible galactopyranose conformations, each of which conformations is within the scope of the terms cellulose and cellulose acetate as used in the present invention, are illustrated by the following formulas:



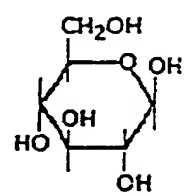
α-L-Glucopyranose



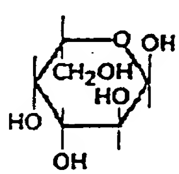
α-D-Glucopyranose



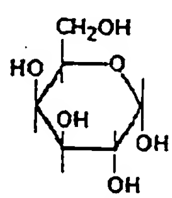
β-L-Glucopyranose



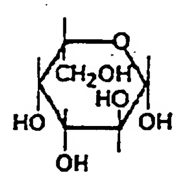
β-D-Glucopyranose



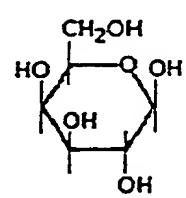
α-L-Galactopyranose



α-D-Galactopyranose



β-L-Galactopyranose



β-D-Galactopyranose

Fig. 1 shows the synthesis of a cellulose cinnamate according to an embodiment of the present invention. A cinnamic

acid is first prepared by reacting a benzaldehyde with malonic acid in pyridine and piperidine. The cinnamic acid is then reacted with thionyl chloride to produce a cinnamoyl chloride derivative. The CelCN is finally synthesized by reacting cellulose, or cellulose acetate, with the cinnamoyl chloride derivative in an inert solvent (such as chloroform, nitrobenzene, chlorobenzene, or the like). The reaction mixture is diluted with methanol, filtered, dried in a vacuum, and milled by a vibrating mill, whereupon the CelCN is obtained.

A process of forming an alignment layer according to an embodiment of the present invention comprises the following three steps.

First, a polymer solution is prepared using chloroform ($CHCl_3$) as a solvent. The concentration of the polymer determines the ultimate thickness of the alignment layer on the LCD substrates. To form a film having a thickness of approximately 1 μm, a CelCN solution of 10 g/l is selected for coating the substrate.

Second, a drop of the CelCN solution is placed in the center of the substrate using a measuring pipette, followed by spin-coating while centrifuging at a rotation speed of 3000 rpm for 30 seconds. The produced film is immediately prebaked at 180 °C for

1 hour.

Third, the initially isotropic polymer film is irradiated with polarized UV light having a wavelength λ below 365 nm to render it anisotropic, with either a positive or a negative dielectric. The irradiation time is more than 5 seconds, and the intensity of UV light is about 5 mW/cm².

Fig. 2 illustrates a scheme of light irradiation of a photo-alignment layer of the present invention.

As shown in Fig. 2, an embodiment of the light irradiating procedure utilizes a substrate 100, a photo-alignment layer 50 including a CelCN on substrate 100, a lamp 10 for irradiating UV light over photo-alignment layer 50, and a polarizer 30 for polarizing the light irradiated from lamp 10.

Lamp 10 is a Halogen (Hg) lamp. Light having an average power of 500 W is transmitted from a lens of the halogen lamp, polarized by polarizer 30, and irradiated onto photo-alignment layer 50 at a power of 5 mW/cm² for about 0.5 to about 180 seconds, more preferably about 0.5 to about 60 seconds, and most preferably about 3 to about 60 seconds.

The alignment obtained from the CelCN polymers of the present invention has a stronger anchoring energy compared with the alignment obtained from conventional photo-alignment

materials. The values of the anchoring energy of CelCN versus typical prior art photo-alignment materials, including polyvinyl fluorocinnamate (PVCN-F) and polysiloxane cinnamate (PSCN), have been measured. The results are shown in the following TABLE 1:

TABLE 1

Material	**Irradiation Time (seconds)**	**Anchoring Energy (erg/cm^2)**
cellulose 4-fluorocinnamate	5	greater than 10^{-2}
cellulose 4-fluorocinnamate	300	greater than 10^{-2}
polyvinyl-flucrocinnamate	5	3×10^{-4}
polyvinyl-flucrocinnamate	300	10^{-2}
polysiloxane-cinnamate	5	bad alignment; measuring failure
polysiloxane-cinnamate	300	5×10^{-3}

To estimate the thermostability of the CelCN, the quality of the alignment layer was checked using an electro-optical technique. Electro-optical response, in terms of cell

transparency ratio between crossed and parallel polarizers, anchoring energy and surface density of the alignment layer were each measured in a twisted nematic (TN) cell containing samples of the CelCN layers. The cell was heated to about 120 °C and kept at this temperature for 4 hours. After cooling the samples to room temperature, it was revealed that the performance characteristics were maintained unchangeably.

Among its other advantages, the present invention thus significantly reduces UV irradiation time. Whereas prior art photo-alignment techniques involved UV irradiation for anywhere from 5 to 10 minutes, the present invention provides a method which successfully achieves photo-alignment using UV irradiation in anywhere from about 0.5 seconds to one minute.

Preferred embodiments of the present invention will now be described in further detail. It should be understood that these examples are intended to be illustrative only and that the present invention is not limited to the conditions, materials or devices recited therein.

EXAMPLE 1

– Synthesis of 4-fluorocinnamic acid –

A mixture of 0.1 mol 4-fluorobenzaldehyde, 0.15 mol malonic acid, and 0.1 ml piperidine in 30 ml pyridine is boiled for 10 hours, cooled, and treated with 150 ml HCl having a 10 % concentration. The precipitate is filtered and crystallized with ethanol. The yield of 4-fluorocinnamic acid is 68 % and the melting point is 211 °C.

The following compounds are synthesized in a similar manner:

2-fluoro cinnamic acid;

3-fluoro cinnamic acid;

3-chloro cinnamic acid;

4-chloro cinnamic acid;

2-methyl cinnamic acid;

4-phenyl cinnamic acid;

4-methoxy cinnamic acid;

4-pentoxy cinnamic acid;

4-heptyloxy cinnamic acid;

4-nonyloxy cinnamic acid;

4-(4-pentoxyphenyl)cinnamic acid;

4-trifluoromethoxy cinnamic acid;

4-trifluoromethyl cinnamic acid;

4-pentyl cinnamic acid; and

4-methoxy-3-fluorocinnamic acid.

EXAMPLE 2

- Synthesis of cellulose cinnamate -

A mixture of 0.05 mol cinnamoyl chloride (prepared from a cinnamic acid produced in Example 1, an excess of thionyl chloride, and catalytic quantities of dimethyl formamide), 0.01 mol cellulose, and 0.04 mol pyridine in 20 ml nitrobenzene is heated for 24 hours at 120 °C, cooled, and diluted with methanol. The reaction product is filtered, washed with methanol and water, dried in a vacuum, and subsequently milled by a vibrating mill.

Pyranose polymers are produced in the above manner using each of the cinnamic acids produced in Example 1. The yield of cellulose cinnamate is approximately 65% to 92%. Thin layer chromatography (TLC) reveals there is no cinnamic acid in the reaction products.

EXAMPLE 3

- Synthesis of cellulose acetate cinnamate -

A mixture of 0.03 mol cinnamoyl chloride (prepared from a

cinnamic acid produced in Example 1, an excess of thionyl chloride, and catalytic quantities of dimethyl formamide), 0.01 mol cellulose acetate, and 0.03 mol pyridine in 20 ml chloroform is boiled for 24 hours, cooled, and diluted with methanol. The reaction product is filtered, washed with methanol and water, dried in a vacuum, and subsequently milled by a vibrating mill.

Pyranose acetate polymers are produced in the above manner using each of the cinnamic acids produced in Example 1. The yield of cellulose acetate cinnamate is approximately 65% to 92%. Thin layer chromatography (TLC) confirms there is no cinnamic acid in the reaction products.

Fig. 3 is a sectional view of an embodiment of a liquid crystal display device of the present invention.

As shown in Fig. 3, the LCD comprises first and second substrates 100 and 101, respectively, a thin film transistor (TFT) 70 on first substrate 100, a first alignment layer 50 formed entirely over TFT 70 and first substrate 100, a second alignment layer 51 formed on second substrate 101, and a liquid crystal layer 90 injected between first and second substrates 100 and 101.

First and/or second alignment layers 50, 51 include a pyranose or furanose polymer, for example the CelCN shown in Fig.

1. The CelCN provides good uniform alignment in a short irradiation time. For example, irradiation for as little as 0.5 seconds gives a stable alignment.

The pyranose and furanose polymers preferably comprise both photo-sensitive constituents and non-photo-sensitive constituents which are composited in a specific ratio. The pyranose and furanose polymers can be composited with only one constituent from each of photo-sensitive and non-photo-sensitive constituents, or one or more different photo-sensitive and/or non-photo-sensitive constituents.

Suitable photo-sensitive constituents for use in the pyranose and furanose polymers of the present invention include an array of cinnamoyl derivatives, which can include substituents such as hydrogen, fluorine, chlorine, cyano, trifluoromethyl, trifluoromethoxy, $C_{n'}H_{2n'+1}$, $OC_{n'}H_{2n'+1}$, phenyl and $C_6H_4OC_{n'}H_{2n'+1}$, wherein n' is 1 to 10.

Suitable non-photo-sensitive constituents for use in the pyranose and furanose polymers of the present invention include various ester derivatives, such as $-\underset{\underset{O}{\|}}{C}-C_nH_{2n+1}$, wherein n is 1 to 10.

When UV light is irradiated onto the first and/or second

alignment layers at least once, the alignment angle, the alignment direction thereof, the pretilt angle and the pretilt angle direction thereof are determined and alignment stability of the liquid crystal is achieved.

As the light used in the photo-alignment method, light in the UV range is preferable. It is not advantageous to use unpolarized light, linearly polarized light, or partially polarized light.

Moreover, it is contemplated as within the scope of the present invention that only one substrate of the first and second substrates be photo-aligned using the above-described method while the other substrate is not so treated. If both substrates are photo-aligned, it is within the scope of the invention that the other substrate be treated with polyamide or polyimide as the alignment material and that the alignment be accomplished by prior art rubbing methods. It is also possible to use a photo-sensitive material such as polyvinyl cinnamate (PVCN) or polysiloxane cinnamate (PSCN) as the alignment material for the other substrate and accomplish the alignment using photo-alignment methods.

As to the nature of liquid crystal layer 90, it is possible to align the long axes of the liquid crystal molecules parallel

with the first and second substrates to produce a homogeneous alignment. It is also possible to align the long axes of the liquid crystal molecules perpendicular to the first and second substrates to achieve a homeotropic alignment. Moreover, it is possible to align the long axes of the liquid crystal molecules with a specific predetermined angle in relation to the substrates, with a tilted alignment in relation to the substrates, with a twisted alignment in relation to the substrates, or in an alignment parallel to one substrate and perpendicular to the other substrate to provide a hybrid homogeneous-homeotropic alignment. It is thus essentially within the scope of the present invention to apply any mode of alignment of the liquid crystal molecules in relation to the substrates as may be desired, such choices being apparent to one of ordinary skill in the art.

The first and/or second alignment layers can be divided into two or more domains by creating different directional alignments of the liquid crystal molecules on each domain in relation to the direction of the substrates. Accordingly, a multi-domain LCD such as a 2-domain LCD, a 4-domain LCD, and so on can be obtained, wherein the liquid crystal molecules in each domain are driven differently.

An LCD made in accordance with the embodiments is characterized by excellent thermostability. It is thus possible to inject the liquid crystal into the liquid crystal device at room temperature while preventing and avoiding any flowing effect from generating, as occurs in conventional techniques. Furthermore, the photo-alignment layer of the embodiments possess excellent photosensitivity, adhesion, and strong anchoring energy. As a result, it is possible to align the liquid crystal effectively and increase alignment stability of the liquid crystal.

CLAIMS

1. A liquid crystal display device, comprising:

first and second substrates;

a first alignment layer including a pyranose polymer on said first substrate; and

a liquid crystal layer between said first and second substrates.

2. The liquid crystal display device according to claim 1, further comprising a second alignment layer on said second substrate.

3. The liquid crystal display device according to claim 2, wherein said second alignment layer includes a material selected from pyranose polymers, a furanose polymers, polyvinyl cinnamate, polysiloxane cinnamate, polyvinyl alcohol, polyamides, polyimides, polyamic acid and silicon dioxide.

4. The liquid crystal display device according to claim 1, 2 or 3, wherein liquid crystal in said liquid crystal layer has a positive dielectric anisotropy.

5. The liquid crystal display device according to claim 1, 2 or 3, wherein liquid crystal in said liquid crystal layer has a negative dielectric anisotropy.

6. The liquid crystal display device according to any preceding claim, wherein at least one of said first and second alignment layers is divided into at least two domains, for driving liquid crystal molecules in said liquid crystal layer differently on each domain.

7. The liquid crystal display device according to any preceding claim, wherein liquid crystal molecules in said liquid crystal layer align homogeneously in relation to at least one of said first and second substrates.

8. The liquid crystal display device according to any of claims 1 to 6, wherein liquid crystal molecules in said liquid crystal layer align homeotropically in relation to at least one of said first and second substrates.

9. The liquid crystal display device according to any preceding claim, wherein liquid crystal molecules in said liquid crystal layer are arranged in tilted alignment in relation to at least one of said first and second substrates.

10. The liquid crystal display device according to any one of claims 1 to 8, wherein liquid crystal molecules in said liquid crystal layer are arranged in twisted alignment in relation to at least one of said first and second substrates.

11. The liquid crystal display device according to any of claims 1 to 6, 9 and 10, wherein liquid crystal molecules in said liquid crystal layer align homogeneously in relation to one substrate of said first and second substrates and align homeotropically in relation to another substrate of said first and second substrates.

12. The liquid crystal display device according to any preceding claim, wherein said pyranose polymer includes at leat one photo-sensitive constituent and at least one non-photo-sensitive constituent.

13. The liquid crystal display device according to claim 12, wherein said photo-sensitive constituent is a cinnamoyl derivative.

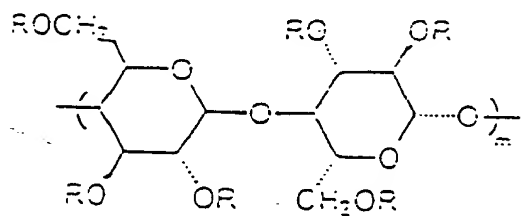
14. The liquid crystal display device according to claim 13, wherein said cinnamoyl derivative includes at least one member selected from hydrogen, fluorine, chlorine, cyano, triflurometlhyl, triflurometlhoxy, C_nH_{2n-1}, OC_nH_{2n+1}, phenyl and $C_6H_4OC_nH_{2n+1}$, wherein n is 1 to 10.

15. The liquid crystal display device according to claim 12, 13 or 14, wherein said non-photo-sensitive constituent is an ester derivative.

16. The liquid crystal display device according to claim 15, wherein said ester derivative is $-\underset{\underset{O}{\|}}{C}-C_nH_{2n-1}$

and n is 1 to 10.

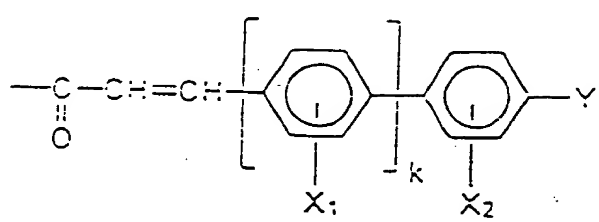
17. The liquid crystal display device according to claim 1, wherein said pyranose polymer is



wherein m is 10 to 10,000;

R is selected from $-\underset{\underset{O}{\|}}{C}-C_nH_{2n-1}$

and



n is 1 to 10;

X_1 and X_2 are each selected from hydrogen, fluorine, chlorine, methyl and methoxy;

k is 0 to 1; and

Y is selected from hydrogen, fluorine, chlorine, cyano, trifluromethyl, trifluoromethoxy, $C_{n'}H_{2n'+1}$ and $OC_{n'}H_{2n'+1}$, wherein n' is 1 to 10.

18. The liquid crystal display device according to claim 17, wherein said pyranose polymer has 0 to 2 $-\underset{\underset{O}{\|}}{C}-C_nH_{2n+1}$ constituents per glucopyranose ring, and n is 1 to 10.

19. The liquid crystal display device according to any one of the preceding claims, wherein said pyranose polymer is cellulose 4-fluorocinnamate.

20. A liquid crystal display device, comprising:

first and second substrates;

a first alignment layer including furanose polymer on said first substrate; and

a liquid crystal layer between said first and second substrates.

21. The liquid crystal display device according to claim 20, further comprising a second alignment layer on said second substrate.

22. The liquid crystal display device according to claim 21, wherein said second alignment layer includes a material selected from pyranose polymers, furanose polymers, polyvinylcinnamate, plysiloxanecinnamate, polyvinylalcohol, polyamides, polyimides, polyamic acid, and silicon dioxide.

23. The liquid crystal display device according to claim 20, 21 or 22, wherein liquid crystal in said liquid crystal layer has a positive dielectric anisotropy.

24. The liquid crystal display device according to claim 20, 21 or 22, wherein liquid crystal in said liquid crystal layer has a positive dielectric anisotropy.

24. The liquid crystal display device according t claim 20, 21 or 22, wherein liquid crystal in said liquid crystal layer has a negative dielectric anisotropy.

25. The liquid crystal display device according to any one of claims 20 to 24, wherein said first or second alignment layer is divided into at least two domains, to drive differently liquid crystal molecules in said liquid crystal layer on each domain.

26. The liquid crystal display device according to any of claims 20 to 25, wherein liquid crystal molecules in said liquid crystal layer align homogeneous against said first or second substrate.

27. The liquid crystal display device according to any of claims 20 to 25, wherein liquid crystal molecules in said liquid crystal layer align homeotropic against said first or second substrate.

28. The liquid crystal display device according to any of claims 20 to 27, wherein liquid crystal molecules in said liquid crystal layer align tilted against said first or second substrate.

29. The liquid crystal display device according to any of claims 20 to 27, wherein liquid crystal molecules in said liquid crystal layer align twisted against said first or second substrate.

30. The liquid crystal display device according to any of claims 20 to 25, 28 and 29, wherein liquid crystal molecules in said liquid crystal layer align homogeneous against one substrate of said first and second substrates and align homeotropic against the other substrate.

31. The liquid crystal display device according to any of claims 20 to 30, wherein said furanose polymer comprises at least one photo-sensitive part and at least one non-photo-sensitive part.

32. The liquid crystal display device according to claim 31, wherein said photo-sensitive part is selected from cinnamoyl derivatives.

3. The liquid crystal display device according to claim 32, wherein said cinnamoyl derivative includes hydrogen, fluorine, chlorine, cyano, trifluoromethyl, trifluoromethoxy, $C_{n'}H_{2n'+1}$, $OC_{n'}H_{2n'+1}$, phenyl or $C_6H_4OC_nH_{2n+1}$ (n is 1 to 10).

34. The liquid crystal display device according to claim 31, 32 or 33, wherein said non-photo-sensitive part is selected from ester derivatives.

35. The liquid crystal display device according to claim 34, wherein said ester derivative is $-\underset{\substack{\| \\ O}}{C}-C_nH_{2n+1}$

(n is 1 to 10).

36. An alignment layer for a liquid crystal display device, wherein the alignment layer includes a pyranose polymer and/or a furanose polymer.

37. A liquid crystal display device substantially as hereinbefore described herein with reference to and as illustrated in the accompanying drawings.

38. An alignment layer for a liquid crystal display device, substantially as hereinbefore described herein with reference to and as illustrated in the accompanying drawings.